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***Investment in Next Generation Networks and the Role of
Regulation: A Real Option Approach***

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Investment in Next Generation Networks and the Role of Regulation: A Real Options Approach[#]

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Abstract

The current regulatory debate in the telecommunications industry in Europe and elsewhere is dominated by the issue of if and how to regulate next generation networks (NGN) which operators plan to roll out in the near future. The crucial issue is whether an extension of current regulatory obligations onto future networks would hamper the investment by large European operators. The paper applies a real option model to explain the investment decision in next generation networks. One important result of the model is that regulation affects the investment decision only in the initial period when uncertainty is still very high. The real option model has been calibrated with parameters drawn from real data for a new entrant and from educated estimates for an established operator. Four different regulatory regimes and their impact on the timing of the investments have been simulated: a temporary regulatory holiday is shown to be an effective regulatory tool in order to induce immediate investments.

JEL Classification Numbers: L51, D81, G11, G35

Keywords: real options, telecommunication, regulated industries, Next Generation Networks.

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1 – Introduction

The current regulatory debate in the telecommunications industry in Europe and elsewhere is dominated by the issue of next generation networks (NGN). The term refers to the installation of high-speed physical infrastructures, largely based on optical fibre, and to the use of platforms based on IP (Internet Protocols) for the transmission of integrated services for voice, data and video. Under many respects the NGNs represent a dramatic technological shift in the provision of telecom services: new networks enable a bandwidth up to 100 megabits per second, as compared to the maximum of 20 megs currently available on DSL platforms. On the other hand, NGNs require massive investments by telecom operators, of the order of several billion euros in a single country, in the face of a widespread demand and regulatory uncertainty. Demand uncertainty arises because the new networks are instrumental to a host of new services for residential and corporate customers, such as Internet TV, e-government, e-health, e-learning and so on, whose acceptance with final customers is still to be ascertained. Regulatory uncertainty arises because, at this stage, it is still unclear whether regulators are going to carry over current obligations on traditional services to NGNs or to apply more lenient rules – even, possibly, a regulatory forbearance as in the US - taking into account that, differently from traditional networks built at the time of the state monopoly, NGNs do not exist yet. A summary of the regulatory debate in Europe will be provided below. Investment in NGNs has been relatively subdued until now: operators want to know the future regulation of NGNs and to have a better guess of demand perspectives, before committing a vast amount of resources to the new networks.

This paper purports to examine the investment decision in NGNs by telecom operators, in the light of high demand uncertainty. To do so we exploit the real option theory, which allows us to include the postponement of investment among the options available to firms. Once the base case is defined and calibrated, different regulatory solutions will be analysed and their implications for the timing of the investment discussed.

The paper is organised as follows. In section two we give a brief overview of regulation and investments, notably by providing stylised facts for the next generation networks and a review of the literature. In section three we explain how real option theory works. Section four describes the model employed to test the impact of different regulatory regimes on investments in next generation network and discusses regulatory options. Section five provides our conclusions.

2 – Regulation and Investment

2.1 – The next generation networks

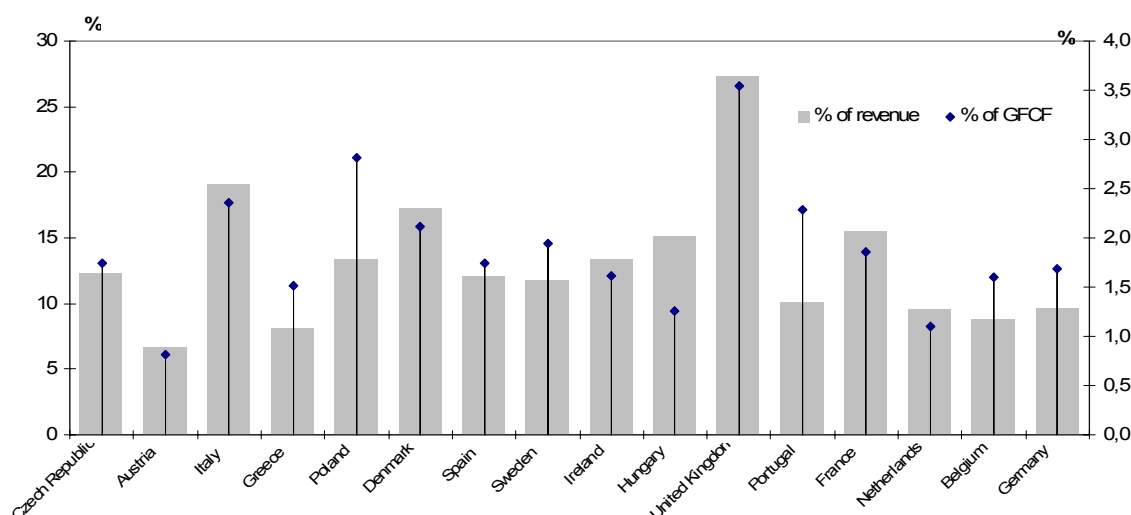
In the OECD countries (OECD, 2007), investments in telecommunication networks has been characterised by a record growth in the period up to 2000 and by a subsequent strong decrease, from a value of USD 243 billion in 2000¹, which includes investment in tangible infrastructures², to below USD 160 billion in 2005. Such a decrease was mainly due to two factors: i) the end of the massive initial investments in access and backbone infrastructures, both fixed and mobile, by new entrants in the telecommunication market, led by over-optimistic expectations on the pick up of Internet services; ii) the end of the financial bubble in the telecommunication industry, that pressed operators and capital markets to be more focused on obtaining an adequate return on investment³.

¹ Corresponding to more than three times the total investment in the sector a decade earlier. The figure includes auctions for licences to spectrum allocated for 3G (UMTS, IMT-2000) services for most of the European countries, with the exceptions of Denmark, Greece, Luxembourg, Poland and Sweden.

² Following OECD (2007), the main drivers for this raise in investments were construction of second generation wireless networks, the entry of new competitors into local access markets for fixed networks, and very large commitments by new entrants and incumbents in national and international backbone infrastructure.

³ As one of the typical problems during the financial bubble was the funding of business plans in terms of coverage and demand, nowadays new entrants tend to be more focused on a local or regional level (*e.g.* fixed wireless ISPs) rather than trying to become a national service provider. The bubble in financial markets was at least partially caused by the same over-optimistic expectations on the future of Internet which lie at the heart of the massive build-up of capacity (on this see Gavosto, 2003).

Figure 1 –Public telecommunication investment as a percentage of PTO revenue
and gross fixed capital formation (GFCF)
(2005)



Source: adapted from OECD (2007).

The slowdown in investment that dates back to the beginning of the decade is probably coming to an end. On the one hand, the excess capacity that has characterised the decade as a consequence of the massive build-up of transmission infrastructures from 1995 to 2000 is finally being eroded by the dramatic increase in demand for broadband Internet⁴. Broadband connections all over Europe have jumped from 52.6 million in 2005 to over 70 million in 2007 (European Commission, 2007a). On the other hand, the technological paradigm is shifting. Differently from the leading ADSL technology, where traditional analogue voice services and digital data transmission for Internet run over two different platforms, in next generation networks voice (typically, voice over IP), music, videos and all other sort of data are transported over the same integrated network.

⁴ According to standard definitions, broadband includes speeds over 125 megabits/sec, as compared to traditional dial-up Internet which reaches 56 megabits/sec. In Europe (Eu 25) broadband connections are offered mainly on copper twists through DSL technology. Other types of connections are modem cable (15%), optical fiber (1%) and satellite (0,19%).

NGNs will increase bandwidth (i.e. the "speed" of the Internet connections) dramatically, up to 100 megabits per second, which will enable transmission of several channels of high definition television and services such as e-government, e-health, e-learning and so on. Therefore, the next generation networks will be the leading driver of the future investment in telecommunication networks. The European debate mainly concerns the deployment of NGNs at the access (i.e. local loop) level: in this paper we will concentrate on access NGNs.

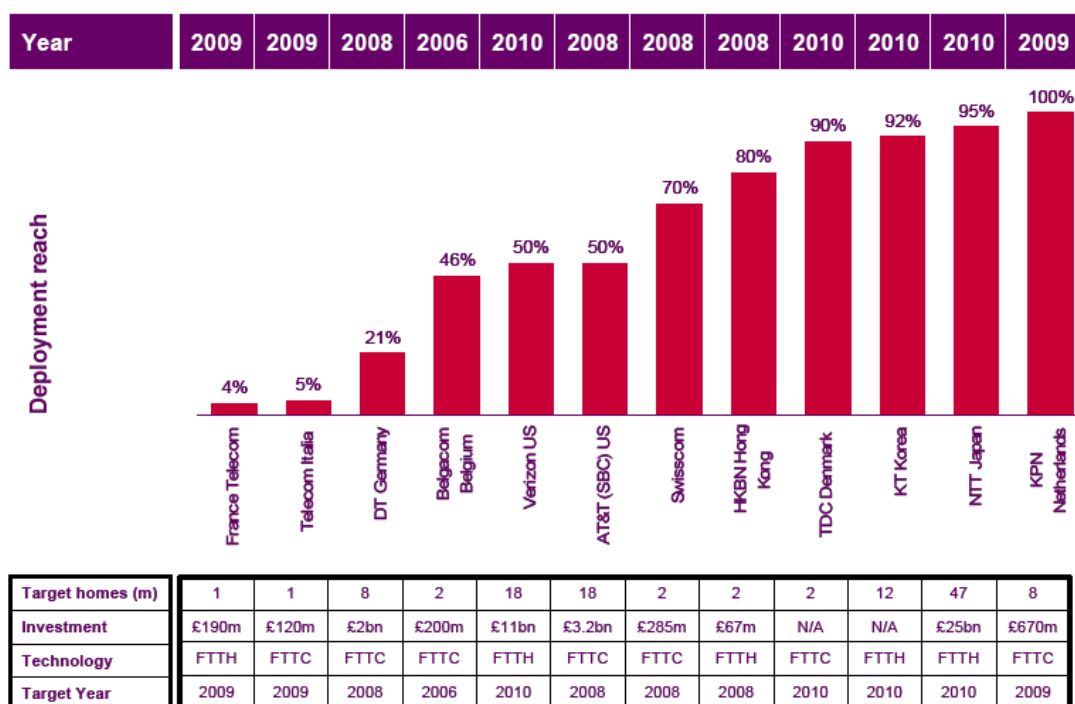
Laying fibre up to the customer's premises or close to it represents a serious financial effort, mainly due to the cost of obtaining building permits and of engineering works in urban and rural areas, which together represent from 50 to 80% of the overall capital expenditure⁵. So far, the main European operators have announced preliminary plans of investment (see Figure 3). In Italy, Telecom Italia expects to invest between 6 and 7 billion euros in next generation networks by 2015. Such an effort will be tuned according to the increase of demand for services based on NGNs.

Next generation networks have the potential to offer substantial economic benefits. They can:

- lower substantially operating costs, (instead of several networks, each with its own provisioning and maintenance procedures, a NGN carries all traffic on a single network);
- allow operators to develop services more quickly and more cheaply because intelligence is centralised rather than embedded in switches, (this in turn allows them to experiment with services to find out which ones best meet end user needs);
- deliver higher functionality services, (because of their ability to integrate and bundle services).

In other words, NGNs can both lead to cost savings in the provision of services and enhance revenues by enabling brand new service.

Figure 3 –Incumbent next generation access deployment plans by target date



Notes: in euro terms the amounts for each operator are: FT €273m, TI €172m, DT €2,8bn, Belgacom €287, Verizon €16bn, AT&T €4,5bn, Swisscom €409m, HKBN €96m, NTT €36bn, KPN €962m.

Source: adapted from Ofcom (2007).

The pace with which these potential benefits are realised will clearly depend on how NGNs are regulated. The regulatory question for NGNs is quite well defined (its solution less so, as we will see). Differently from the usual regulatory problem in telecommunications – that is the opening up to competition of a legacy infrastructure, the copper network, built during the monopoly years – the question here is how to define future rules for networks which do not exist yet. The relevant trade off is between the incentive to investment and the degree of competition in the future telecommunication market. On the one hand, in fact, established operators, which will, inevitably, sustain most of the investment in several countries, are waiting to see whether regulatory authorities decide to

⁵ See the European Commission recent *Impact Assessment* (European Commission, 2007b).

impose permanent regulation⁶ wholesale obligations on the next generation networks, such as the ones which exist presently on traditional networks: typically the obligation to provide access to the established operator network elements (for instance, the local loop) at a price which corresponds the full distributed cost of the service, as recorded in the regulatory accounting. If this were the case, one could surmise that established operators face fewer incentives to build NGNs, as regulation will immediately wipe out the quasi-rents arising from the deployment of new infrastructures. Symmetrically, the existence of wholesale obligations, and their scope, will also condition the behaviour of the new entrants, which may either decide to make major investments or to exploit the established operators' NGN as the latter are gradually installed (free riding behaviour), thus side-stepping significant fixed costs.

On the other hand, regulatory bodies are concerned about removing any initial conditions of major advantage to the established operator that could preclude the development of a competitive market. The potential advantages are represented, on the one hand, by the exclusive availability of some network elements (such as reconnections from the cabinet to the user's premises or the ducts in which to install the fibre); on the other hand, by the control of an initial customer base which could enable the established operator to reach significant network economies before its competitors. For these reasons, regulators such as the European Commission are quite hostile to regulatory forbearance and regulatory holidays, that is the absence of all obligations on NGNs for at least a pre-defined period of time, as imposed by the German telecommunications bill (and fiercely opposed by the Commission)⁷.

2.2 – Literature review

In highly capital intensive industries the launch of a new service or a technology often involves lumpy investments. Such investments are not necessarily carried out at the time when the investment opportunity arises, even if they are profitable (in the sense that they

⁶ As we have defined it at page 33.

⁷ See the European Commission recent *Impact Assessment* for details (European Commission, 2007b).

would produce a positive discounted cash flow). Often investment opportunities are held “on the shelf”.

It is generally agreed (Guthrie, 2006) that one of the main reason for this delay is the nature of the regulatory framework. Accordingly, economic literature on the impact of regulation on investments is divided into two areas of research: (i) standard investment analysis where the impact of regulation (either rate-of-return or incentive regulation) is usually evaluated in a static context, although occasionally dynamic models of investment behaviour⁸ are applied; and (ii) real options approach.

Several authors have focused their attention on the realistic rate of return for a regulated firm but none has been able to find a solution in the case of firms which undertake irreversible investments while constrained by incentive regulation with periodic retunes⁹.

Other authors have integrated uncertainty and irreversibility in their models and have considered the more general problem of setting regulated prices when faced with non-constant demand and technology¹⁰. Beard et al. (2003) employ a two-period model in which a regulator decides (i) the revenues which a firm is authorized to earn in the case that its assets are not stuck, and (ii) the reward which the firm will obtain if its assets are stranded. The less reward offered, the more profit must be allowed if the firm is to voluntarily invest in the project. As a result, full compensation would not be given by a welfare-maximizing regulator.

Conversely the real option approach captures the notion that, in the real world, demand, technology, factor prices and other parameters affecting investment decisions are subject to many uncertainties¹¹. As a consequence it may be in the company’s own interest to delay the investment in order to acquire more information and ultimately to reduce risk. In

⁸ A survey of the static and dynamic models of investment under different forms of regulation and optimal (Ramsey) pricing may be found in Biglaiser and Riordan (2000). Most of this literature assumes static models of which the Averch-Johnson is the best known (1962). These models show that rate-of-return regulation does not provide the incentive for the firm to minimize costs or capital investments.

⁹ Evans and Guthrie (2005) provide an extensive review of the topic.

¹⁰ Dobbs (2004) estimates the firm’s choice of the level and timing of investment when constrained to a price cap which is proportional to the established capital price; that is, the cap varies with the replacement cost of the firm’s assets.

¹¹ The literature on real-options research from the financial perspective is reviewed and integrated in Trigeorgis (1996); Hull (2000) has an extensive coverage of options, as does Luenberger (1998). See Smith and Nau (1995) for the relationship between decision trees and real options.

particular, in these models, regulation can restrict the flexibility of the firm through the introduction of constraints on prices and on costs associated with delay, abandonment, or shutdown/restart options.

Although investment decisions in the telecommunications industry often involve both irreversibility and uncertainty, a limited literature exists on the application of real options to the telecommunications industry¹².

In this paper we extend McDonald and Siegel (1986), who initiated the theory of irreversible investment under uncertainty in a continuous time setting – later extensively developed by Dixit and Pindyck (1994) –, by considering investments which have finite lifespan, whose length is known in advance. Also we use a discrete time setting rather than the continuous one employed by McDonald and Siegel.

In the next sections, we will present an illustrative example of the decision process of firm according to real option theory; subsequently we will describe our model and apply it to NGNs; finally we will compare the impact of different regulatory regimes onto investments.

3 – A real option theory approach to the telecommunication industry

3.1 – A discrete binomial model: an illustrative example

In this section we present an illustrative example with the aim at making the reader acquainted with the reasoning behind the optimal exercise of an option. We also introduce the concept of critical values (i.e. prices above which the option holder should rationally exercise the option) and examine how do these values vary in response to a change in the

¹² Hausman (1999) and Pindyck (2003) applied the real options methodology to examine the sunk cost of assets and the delay option in the context of unbundled network elements, arguing that the regulator has not considered the impact of investment irreversibility when calculating rates of return of firms' investment incentives. Ergas and Small (2000) examined the sunk cost of assets and the regulator's impact on the distribution of returns. Small (1998) studied investment under uncertain future demand and costs with the real options method. Nevertheless, these studies do not address the investment decision, they simply aim at calculating the real option surcharge to be included in wholesale products prices. Among others see Hausman (1997; 1999)

model inputs (stock volatility, risk free interest rate, pay out ratio, option lifespan, etc). Finally, we develop the parallel between a financial option and a business opportunity and we examine how it works in a discrete time setting.

The example is framed within a discrete multiplicative binomial event tree. Differently from models in continuous time, such as those by Black and Scholes (1973) and Merton (1973), a discrete setting helps to clarify the economic principles underlying option pricing. The logic that lies behind the solution of discrete time problems and that of continuous time problems is exactly the same: often solutions to continuous time problems are found by converting them into equivalent discrete settings. The numbers in this example are chosen to make computations simpler, but nothing of substance is lost.

Let us consider a 3-year time horizon (see Figure 4). At time $t=t_1$, there are two possible states of nature (“Up” and “Down”); at $t=t_2$, there are four possible states of nature (“A”, “B”, “C” and “D”); finally at $t=t_3$ there are eight possible states of nature (“1”, “2”, “3”, “4”, “5”, “6”, “7” and “8”).

Let us suppose that a firm can choose between a risk-free security, worth 1,000\$, which earns 3% per annum, and an investment project which requires a 480\$ disbursement, and whose expected net cash flow are equal to 500\$ (again, the numbers are chosen for the sake of simplicity). The investment opportunity ceases to exist at t_3 i.e. three periods after the investment opportunity arises.

The firm opportunity to invest can be thought as a call option on a stock whose price evolves following the same stochastic process as the expected net cash flow. The strike price, worth 480\$, is equal to the up-front disbursement required to implement the investment and is exogenously given. The financial equivalent of the last date at which the investment can be carried out (i.e. t_3) is to be considered as the option expiry date.

Let us now look at the cost associated with keeping the investment opportunity at bay for one period: each year of delay implies less payout (extra revenues and cost savings) to the company. The equivalent of the opportunity cost in the case of a call option on a quoted

stock is the dividend periodically paid by the company to its shareholders¹³. In the example we assume that the payout is a fixed percentage (10%) of the net present value of the project at the different nodes (in financial terms, this would correspond to the stock price).

At each node the company can either invest 480\$ (exercise the option by paying the strike price) and receive the project NPV¹⁴ (one share of the company) plus the period payout¹⁵ (the dividend) or, conversely, it can decide to postpone the beginning of the investment to the next date (hold the option unexercised). The company decides what to do after the state of nature has revealed itself (i.e. the company knows how much the net present value is worth at that date). We suppose that at t_3 the business opportunity ceases to exist and thus t_3 represents the last chance the company has to start the project (to exercise the option).

We can now describe the company decision process, as illustrated in Figure 4. Each node of the binomial tree is identified by an array of seven numbers. In the first row, we indicate the business opportunity value and whether it is optimal to undertake the investment (grey area) or not. In the second row, first column, we represent the NPV of the project; in the second column, the payout of the project, i.e. the extra revenues and cost savings, at the current date. In the third row, first column, we show the value of the risk free security; in the second column, the period project payout. In the third row, first column, we show the value of the risk free security; in the second column, the state prices of the project payoff which encompass all future information on the states of the nature. Finally, the fourth row includes the value of the business opportunity if not exercised (first column) or exercised (second column): clearly, the value of the option is the greater of the two.

The market formed by the risk-free security and the project allows no arbitrage and it is dynamically complete. Under no arbitrage a set of state prices exist; due to market completeness, it is also unique. We can thus price all contingent claims by the no arbitrage.

¹³ In the case of a NGN deployment the incremental revenues and cost savings (i.e. the investment payout) corresponds respectively to the extra revenues arising from, say, TV on Internet plus the cost savings – mainly in terms of less maintenance and provisioning - induced by the replacement of the current copper access with NGNs.

¹⁴ The NPV of the project is equal to the sum of the payouts from the next date to the date the projects ends.

¹⁵ The period payout is equal to the difference between the extra revenues and cost savings realised by investing today and those that would arise by investing one period later.

At t_0 the value of the project, denoted by S , is assumed to be equal to 500\$. In the following period, t_1 , following the multiplicative binomial stochastic process, the NPV of the project can either go up by 60% to $St_1 = St_0 * (1+0.6)$ or go down by 20% to $St_1 = St_0 * (1-0.2)$. At t_2 the NPV can either go up to $St_2 = St_1 * (1+0.25)$ or go down to $St_2 = St_1 * (1-0.15)$. At t_3 the stock price can either go up to $St_3 = St_2 * (1+0.1)$ or go down to $St_3 = St_2 * (1-0.1)$.

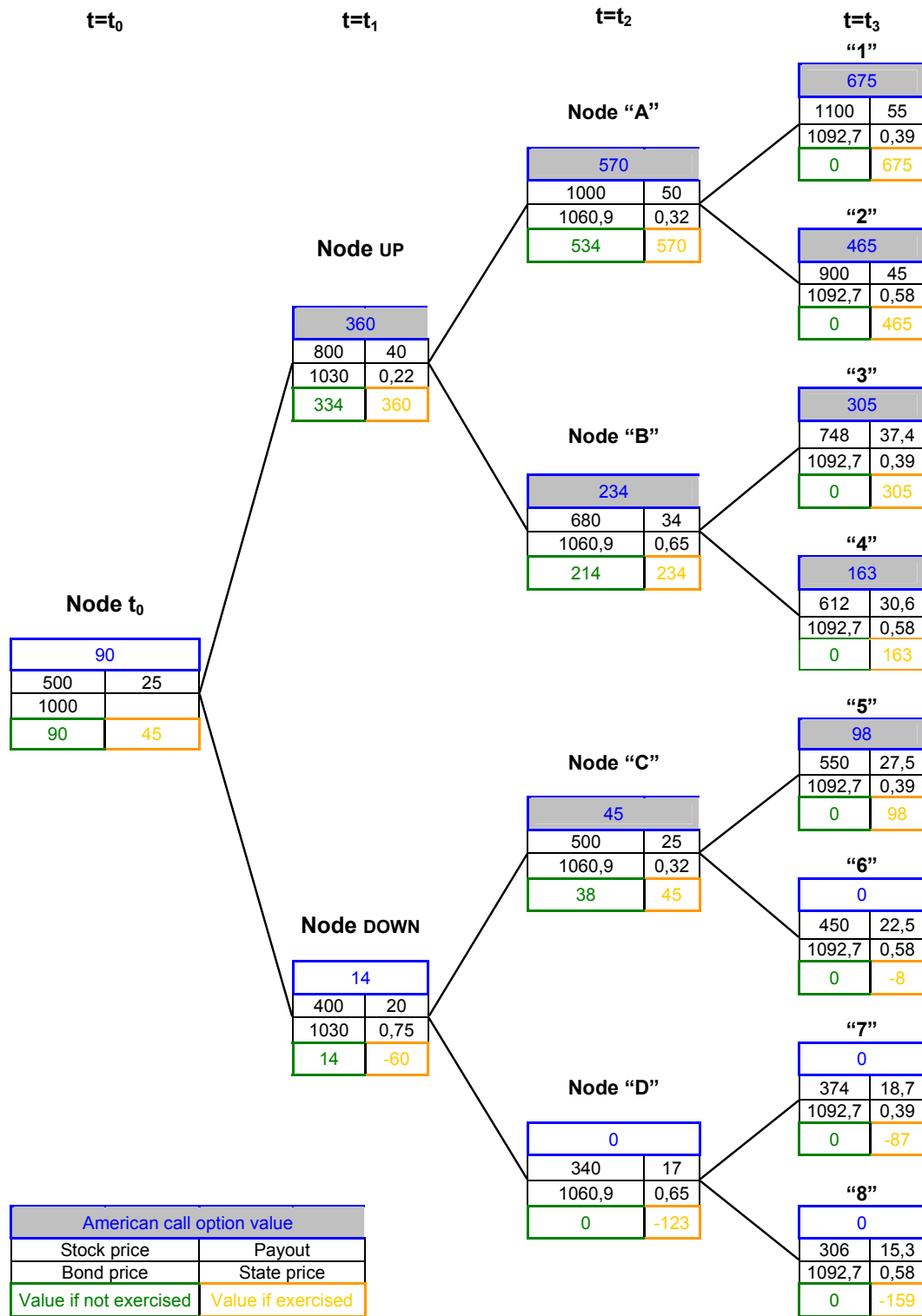
Note that in the example the range of the price changes in each node is chosen to make calculations simple. However it is greater (in absolute value) at the beginning of the project than at the end (60%, -20% versus $\pm 10\%$) in order to capture the idea that as information flows in with time, demand uncertainty falls, and hence the project becomes less risky while earning a constant return. In fact the payout ratio (i.e. the ratio between the one period payout and the NPV) is kept constant through all the project lifespan.

How do we compute the values of the option whether it is exercised or not at each node? If it is exercised, the value of the option, shown in the orange cell (fourth row; second column), is equal to the sum of the current NPV plus the period payout minus the option strike price. If it is not exercised, the value of the option, shown in the green cell (fourth row; first column), is equal to the next period payoffs (associated with adopting the optimal exercise policy) times the state prices¹⁶. The American call option value, contained in the blue cell, is equal to the greater between these two values.

What is the intuition? If the option is exercised, i.e. if the investment is made in the current period, the company will gain the extra revenues and lower costs linked to the immediate investment (the payout) plus the value of the project in all future periods, as captured by the NPV. In exchange, the company has to pay the strike price: for instance, the cost of deploying fibre in the access network. On the other hand, if the option is not exercised at t_n , i.e. the investment has not been yet carried out, its value is a function of the payoffs at t_{n+1} , associated with the optimal exercise policy across all future states of nature. In order to compute the value of the option when not exercised, one has to work backwards through the binomial tree, determining at each node whether or not it is optimal to exercise.

¹⁶ The next period payoffs (associated with adopting the optimal exercise policy) are equal to the value of the American call option at the next date.

Figure 4 –Binomial event tree



Let us begin from the final period. If the option is still not exercised at t_3 , then the optimal policy is as follows: to exercise if the sum of the NPV and the payout (i.e. the payoffs obtained by exercising) exceeds the strike price; not to exercise, otherwise. Once the payoffs at t_3 (associated with the optimal exercise policy) are known, the value of the option at t_2 if not exercised can be computed by backward induction. At t_2 the optimal exercise policy is to exercise if the value of the payoffs received by exercising (payout + NPV) exceeds the value of the unexercised option. By applying the same backward induction we can find the American option value at all previous nodes.

To better understand the difference between the value of the option to invest when exercised and when it is not, we can decompose it into three components¹⁷. The first is the “lost payout”. When the option has been exercised early, say at t_n , the company collects the payout (incremental revenues and cost savings) arisen at t_n . If instead the company holds the option for one extra period, it loses the payout at t_n . On the other hand, by holding the option for one more period, the company benefits from the postponement of the cash outflow: this is the second component. The third component is given by the value associated with protracting the period in which it is possible to choose between the two alternatives: in fact at the subsequent nodes the value of the unexercised option may still exceed the payoffs (payout + NPV) gained by exercising. We will refer to this component as the “reversibility component” which adds to the value of the option when not exercised. At the date prior to expiry (i.e. t_2) the company avoids incurring losses at expiry by postponing the decision to invest. This is why in this case the reversibility component is referred to as the protection value

We can now define the decision rule: an American option is rationally exercised when the value of the payout exceeds the interest cost associated with an early disbursement of the strike price (the “cash-out postponement”) plus the loss of the insurance against the possibility that payoffs at expiry are less than the strike price (the “reversibility or protection value”). In other words, according to the real option model, the investment is carried out when the revenues gained from having implemented the project exceeds the value of the marginal information obtained by waiting from time t_0 to time t_1 plus the

financial benefit due to the fact that the up-front disbursement investment cost (cash outflow) becomes smaller in present value terms.

If volatility is zero or if all possible payoffs at expiry are above the strike price, the insurance component is obviously worth zero, and thus it is optimal to defer the exercise of the option as long as the interest savings exceeds the lost payouts. For example at the UP node of the event tree, the value of the cash outflow deferment is equal to 14.4 (480\$ times the exogenous interest rate of 0.03), whereas the payout is equal to 40. Thus the benefit of exercising exceeds the cost and the option is rationally exercised.

In order to illustrate the decision process on whether to exercise or not it is useful to compare node t_0 and node “C”. In fact, at these two nodes the NPV and the payout are the same; still, as we will see, in the latter case it is optimal to exercise the option while in the former it is not. In our example, the rate of interest is kept constant over the event tree, hence the cash postponement component is exogenously given and the same at both nodes (see Figure 5 and 6). Equally, the lost payout is the same by construction. All the difference is thus given to the reversibility-protection component. In particular, at node t_0 the reversibility component is higher because the array of possible outcomes (payoffs at expiry prices) is much greater than those which can be reached from the node “C”: hence the value of the insurance against “bad” states of nature is much greater. At node “C” the range possible final payoffs decreases substantially since, as time elapses, some final outcomes can no longer be reached and the rate of change of prices at t_2 ($\pm 10\%$) is much smaller than at t_0 ($+60\%$; -20%). In a continuous time setting this is equivalent to saying that the total variance falls with time because the time horizon becomes shorter and the variance per unit of time decreases. In conclusion the optimal strategy is not exercise at t_0 but to exercise at “C”.

¹⁷ The value of the payoff obtained by exercising the option is usually called the intrinsic value of the option.

Figure 5 –Decomposition of the option value at node t_0

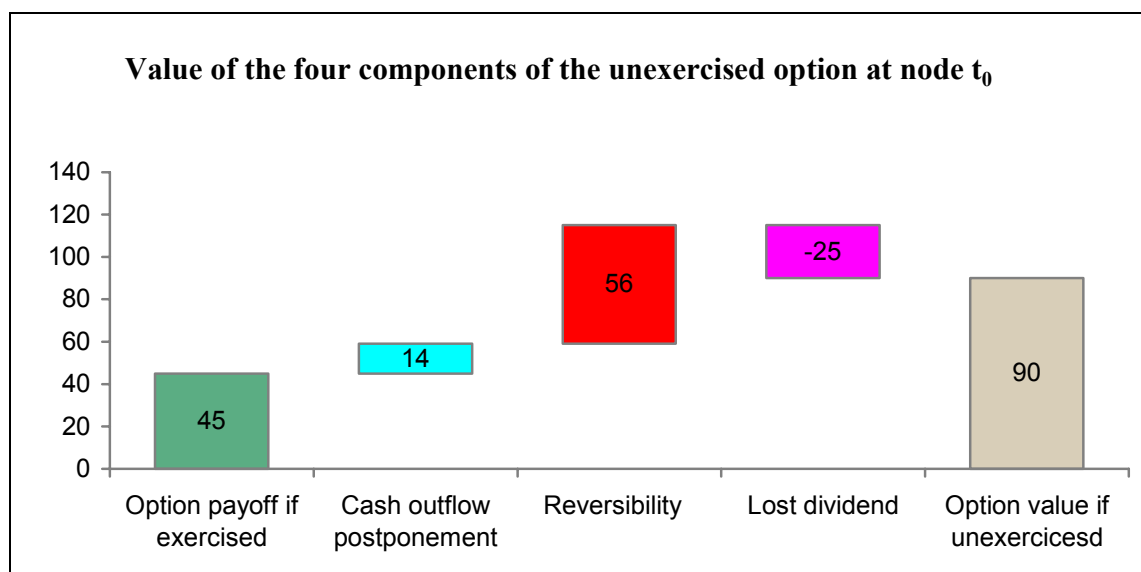
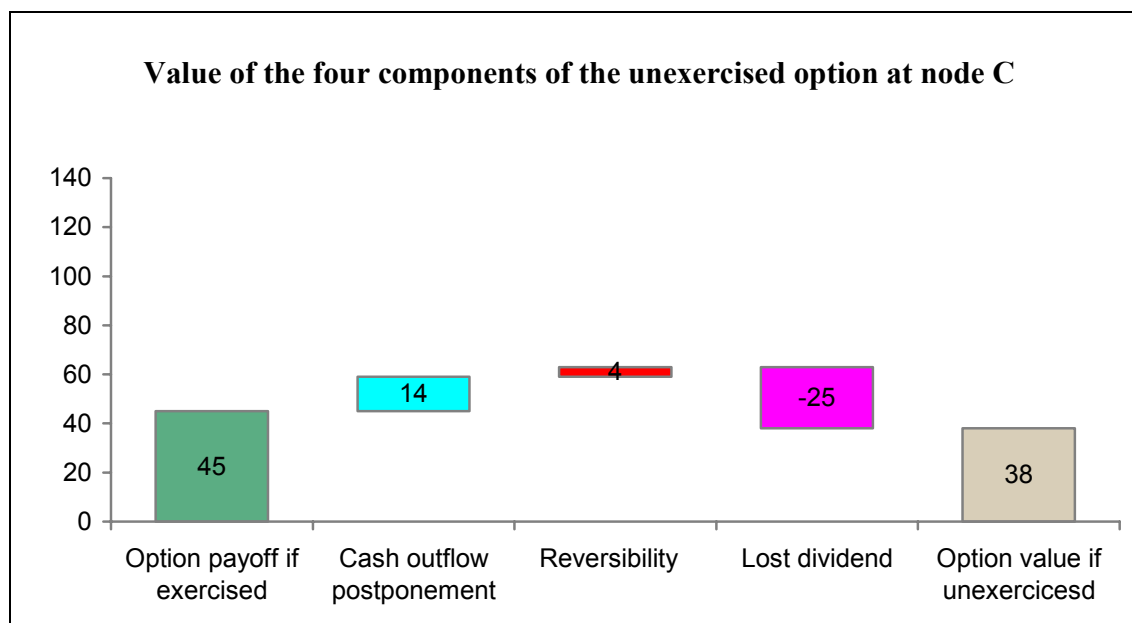


Figure 6 –Decomposition of the option value at node “C”

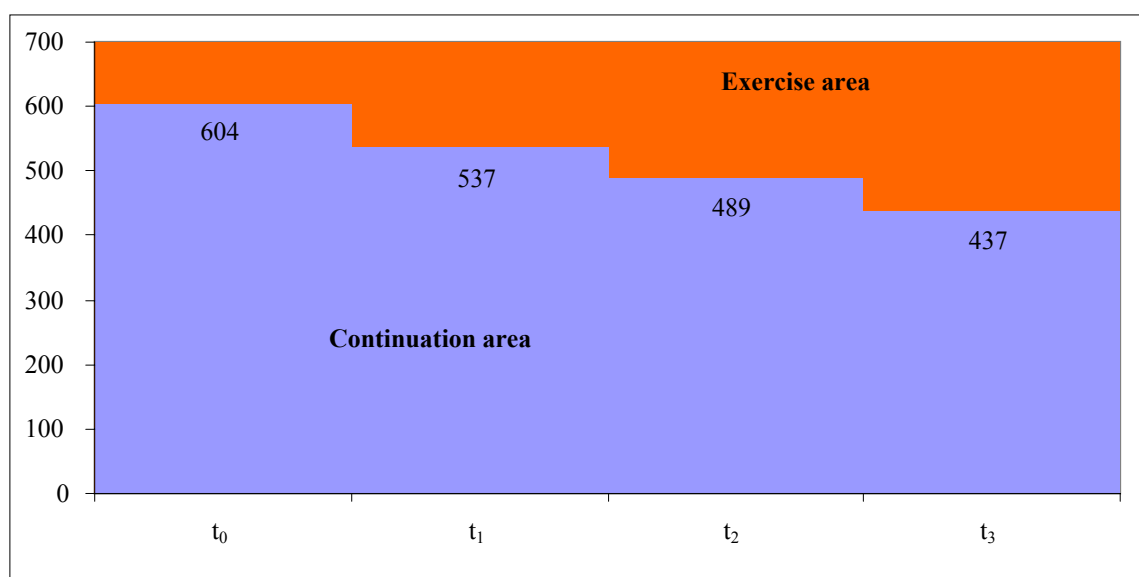


The cash outflow postponement component assumes the same value at t_0 , t_1 and at t_2 while it is zero at t_3 (at expiry the cash outflow cannot be postponed any longer). Moreover it is independent from the project value. The reversibility component decreases with time and at any date t_n it is a monotonic decreasing function of the value of the project. Conversely the opportunity cost (lost payout component) is independent of time, whereas it linearly increases with the value of the project.

A simple argument establishes that at any t_n the optimal stopping policy can be expressed in the following terms: exercise if $S_{tn} > S^*_{tn}$; do not exercise otherwise. The optimal stopping rules reflects the intuition that when the stock price is sufficiently high the probability of incurring losses at expiry is quite low (low protection) while the lost payout due to because of waiting becomes significant (high opportunity cost).

Since the value of protection falls with time, the critical values S^*_{tn} , above which it is optimal to carry out the project, decreases as the date of expiry becomes closer (see Figure 7).

Figure 7 –Critical values $S^*_{t_0}$, $S^*_{t_1}$, $S^*_{t_2}$ and $S^*_{t_3}$



3.2 – Impact of regulation on investment: the issue of truncation

The example of the previous section allows us to highlight one important result of the real option model as far as the impact of regulation on investment is concerned: the fact that the expectation of future regulatory remedies does not tilt the investment decision by the company. This is known as the ‘truncation’ issue.

As we stressed earlier, the central theme of the regulatory debate is whether existing obligations, which basically consists of granting access to the established operator’s network at prices equal to costs, can be extended onto future networks without causing the investment in NGNs to be reduced or even cancelled. The leading view by large operators - which has been represented by LECG (2007) in a paper made for the organisation of incumbent operators - is that an extension of current obligations would lead both incumbents and alternative operators to reduce the amount of investment in NGNs. Established operators would cut back on investment because regulation will make perspective quasi-rents to disappear; on the other hand, alternative operators would rather buy the services from incumbents at regulated prices than make their own infrastructures.

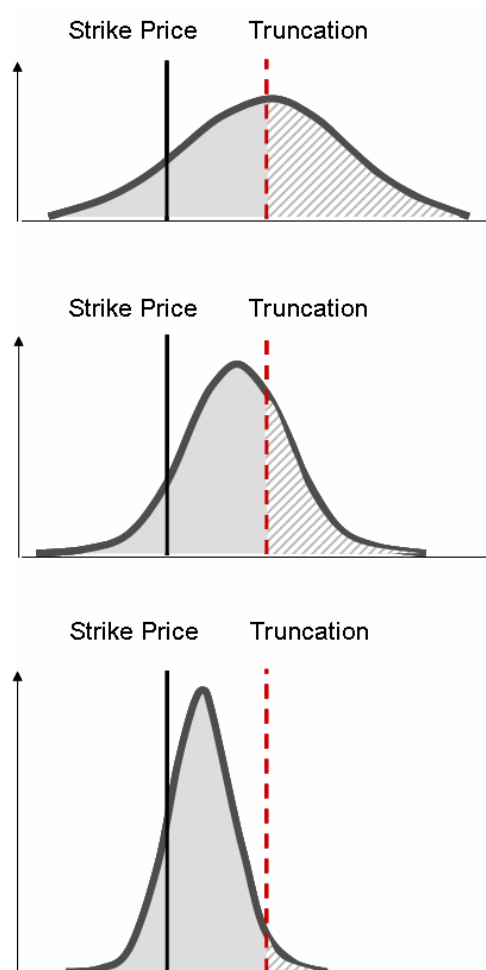
Such a view is echoed by Ofcom, the UK regulator, in a recent document on NGNs: “The imposition of regulatory remedies that mandate access at a specific price may result in asymmetric risk borne by investors and a change to the prospective returns available for an investing firm. However a straight-forward application of the standard cost plus pricing approach may result in lower incentives to invest. This approach would cap the total returns that the firm could make if demand turned out to be high but force the firm to bear all of the losses in the event that there was virtually no demand” (Ofcom, 2007).

Whereas the reasoning by Ofcom is well grounded in traditional finance models, such as the capital asset pricing model, in a real option context this view needs to be qualified. Regulatory intervention that caps the total returns affects investments in NGN negatively *only in the initial period*; in the long run, according to the real option model, investments are not affected.

In order to understand this point, we have to go back to the illustrative binomial example of Section 3.1. As we saw, at all times between t_0 and t_3 the company faces a distribution of

possible NPVs, i.e. the present value of cash flows from the expiry date onwards, which will arise at the expiry date of the option which we assumed to be t_3 . As we move from t_0 to t_3 , the spread of the expected distribution of the NPVs at t_3 becomes smaller, as uncertainty on the project outcome wanes (and the value of reversibility is reduced as a consequence). By the time we reach the expiry date, t_3 , there is hardly any uncertainty left: the distribution collapses to a single value of the net present value of the project, which we assume to be known. As we described earlier, the decision rule is that, if at t_3 the present value of cash flows onwards (NPV) exceeds the strike price, then the investment is carried out; otherwise the investment is waived for ever (see Figure 8).

Figure 8 –Some truncation effects



Now let us suppose that the regulator decides to cap the company's returns by imposing a cap on the overall project rate of return from the expiry date onwards. This amounts to prevent the company from earning the excessive payoffs, i.e. to truncate the right-hand tail of the distribution at the expiry date. As Ofcom correctly points out, the expected return for the company falls under regulation. Does this tilt the decision whether to invest in our model or not? It does not. In fact, in real option models the company decision to invest is exclusively affected by the shape of the distribution below the strike price and not by the shape above the strike price.

Except in the (very unlikely) case that the regulator imposes a rate of returns cap permanently below zero (i.e. cumulative net cash flow falls below the investment disbursement) – that would cause the company to run consistent losses –, the portion of the NPV distribution which lies below the strike price remains unchanged even after the truncation imposed by the regulator: hence the incentives to invest are unaffected. Thus *over the long run*, that is from the expiry date onwards, the investment decision by the company is unaffected by a rate of return cap¹⁸, at least within this real option model.

This result holds true from t_3 onwards. In the initial period, from t_0 to t_3 , when uncertainty over the project outcome still exists, the intervention of the regulator does make a difference, however. In fact, by lowering the payout, the regulator tilts the decision of the company on whether to exercise the option or not by affecting the “lost payout” component. Obligations from the regulator make it more likely that the company postpones its investment decision until t_3 . As we shall see, this finding supports the regulatory prescription of relaxing regulation on NGN in the initial phase of the investment when uncertainty is still high.

¹⁸ Again this is true only if the regulated price allows the company to recover its initial disbursement.

4. – A model to evaluate investment in NGNs.

This paragraph aims at identifying a model for evaluating call options for which premature exercise may be optimal, which captures best the characteristics of the investment in next generation networks by telecommunication operators¹⁹.

In order to apply a real option approach to investments we assume the existence of an asset or of a dynamic portfolio of assets which is perfectly correlated with the investment net cash. The firm's ability to defer an irreversible investment is akin to an American call option. The financial option parallel arises from the fact that the firm has the opportunity - but not the obligation - to undertake an investment at some future moment in time.

In real life managers evaluate investments opportunities on a monthly or quarterly basis. Therefore, models which allow the exercise of the option (and the evaluation of its optimality) at a certain pre-specified (equally spaced) dates reflect business reality better than those framed in continuous time settings: these are known as Bermudan options, since they lie in between American options (which can be exercised continuously) and European ones (which can be exercised only at expiry).

In the telecommunication industry, there is still an enormous uncertainty surrounding the returns on services based on NGNs, as stressed at the outset of the paper. Clearly such services cannot be the same as the current ones based on DSL or similar technologies: if this were the case, there would be little point in incurring a massive disbursement such as the one required by NGNs, whereas operators could upgrade their network incrementally in order to reach higher speed and better quality of service²⁰. Hence NGN services and their prices are still clouded by a vast amount of uncertainty.

Based on past experience, the main uncertainties regarding the project revenues and cost savings would typically unveil themselves within five to seven years from the emergence of the business opportunity. After a certain number of years, the volatility can become so

¹⁹ In the last decades the literature on financial option focusing on valuing call options for which premature exercise may be optimal has been abundant. For a brief presentation of the various techniques and approaches available see Gekse and Shastri (1985).

²⁰ In certain areas where the telecommunications copper network encounters serious bottlenecks or congestion issues, it may be theoretically convenient to invest in NGNs due to the cost savings brought about by the optical fibre, rather than upgrade the existing network. However these case seem very limited in scope.

small that it no longer affects the overall profitability of the projects. This implies that optimal “now or never” decisions are taken before expiry²¹. When the volatility of the project becomes negligible, the reversibility component tends to zero and the remaining lifespan of the option does not affect the optimality rule computed at the previous nodes. In order to model business opportunities whose volatility disappears after a certain number of years, we make use of finitely lived options.

The Cox, Ross and Rubinstein (1979) model lends itself to be employed for finitely lived Bermudan options. It discretises both time and price changes through a recombining symmetric binomial tree. The distribution of dividends and price changes occur at discrete time intervals. Due to the recursive structure of the problem the solution is obtained through iteration.

In the following we will test the model first by applying it to a new entrant operator that decided to invest in FttH technology back in 2005; then to an established operator, which has to decide whether to invest in NGNs on the basis of a number of educated guesses on revenues and costs²².

4.1 – Model input parameters

The Cox *et al.* (1979) model requires the following parameters:

- current expected net present value of the project, denoted by NPV
- up-front investment, denotes by UI
- net cash flow lost by a one year postponement of the project commencement date, denoted by PO (Pay Out) ;
- annualised logarithmic volatility of the project returns, denoted by VOL (Volatility);
- risk free rate, denoted by R_f ;

²¹ An optimal “now or never” decision is a one whose optimality remains unchanged over time.

²² Very few established operators in Europe have already began the deployment of access NGNs.

- number of years after which the sign of the overall project profitability ceases to be a stochastic variable (i.e. years to expiry), denoted by YtE

The model outcomes (option pricing, optimal timing, optimal policy) are homogeneous of degree zero with respect to NPV and UI. This allows to establish the optimality of investments on the basis of the profitability of a single NGN connection. The VOL variable measures the standard deviation of the natural logarithm of projects returns (i.e. ratio of NPV at t_n to NPV at t_{n-1}). The PO variable is expressed as percentage of NPV.

In order to define the VOL parameter, i.e. the NPV annualized volatility, we need to rely on the existence of a NGN pure player which is traded on an exchange market. We have decided base our calibration on Citéfibre, a small scale fibre-to-the home Parisian operator. Citéfibre was established in October 2004 and it was floated on the EuroNext Paris exchange on the 2nd December 2005. After the signature of an agreement with the Municipality of Paris in the beginning of 2005, Citéfibre began the actual fibre rollout in the second half of 2005²³.

In our simulations the initial phase of the project life, the one surrounded by uncertainty, is assumed to last for six years. The parameters of the model can be separated in two categories: general inputs and operators' idiosyncratic inputs. The risk-free rate and years to expiry are both general inputs to the model, while the remaining parameters depend on the characteristics of the specific NGN investment plan (either new entrant's or established operator's).

²³ On 20 october 2006 when Iliad announced the acquisition of CitéFibre, the FttH operator had more than 500 clients, 3,000 kilometres of optical fibres and 130 buildings with optical fibre cabling (representing some 4,000 households potentially connected to the network) in the 15th *arrondissement* of Paris. At that time Citéfibre already held authorisations allowing it to connect another 4,000 households. See: An overview of FiberDirk van der Woude Program manager FttH & broadband services City of Amsterdam August 15th , 2007 edition.

4.1.1 – General inputs

The risk-free rate is assumed to be constant and equal to 5.5% over the first phase of the project. The risk-free rate corresponds roughly to the average cost of money in Europe over the past twenty years.

The number of years after which main uncertainties disappear is assumed to be six years. This is the average time lag between when the front-runner European telecommunication operator adopts a new technology and when the last follower introduces it. The project time optimality is evaluated every quarter.

4.1.1.1 – Citéfibre specific inputs

The actual fibre roll-out of Paris by Citéfibre began in the second half of 2005: this is the date when the investment opportunity was irreversibly converted into a business plan. We make use of the standard hypothesis of rational expectations: as a consequence, we assume that the actual data on the relevant variables (volatility, annual payout and expected NPV) from 2005 onwards correspond to the expectations formed by Citéfibre at the time when the decision was made.

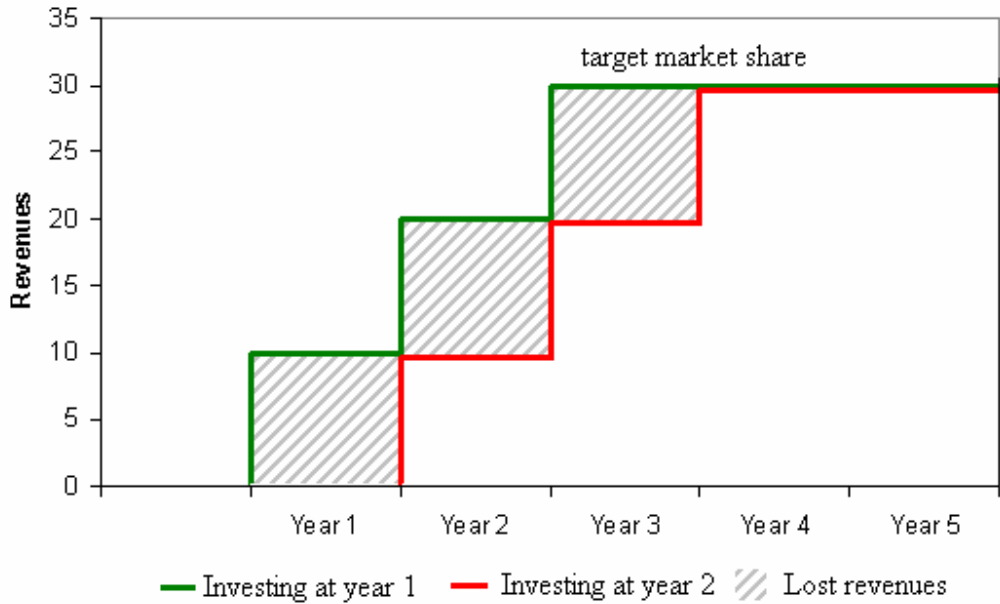
The market expectation of the NPV of cash flows associated with a single fibre connection has been obtained by dividing the enterprise value (market capitalisation + debt) at December 2005 by the expected number of homes passed at the same date²⁴.

The annual payout per connection has been estimated by dividing the 2006 Citéfibre revenues by the average number of the homes passed by the end of 2005 and those passed by the end of 2006. We assume that a one-year investment postponement causes revenues to be lost for the following three years, although by a decreasing amount: hence the initial delay does not lead to a parallel shift over time in the flow of revenues but the gap is filled in a 3-year time horizon. Three years were in fact the expected time by a new entrant such as Citéfibre in order to reach its target penetration. Three years also reflect the average time needed for a new entrant to catch up with the market share reached by operators which had

invested one year earlier (see Figure 9). Thus the value assigned to the payout variable in the Citéfibre case is obtained by multiplying by three the foregone revenues suffered in the period in which the decision to postpone was made.

Per unit up-front costs are estimated by resorting to a study of the investment costs of NGN published by the French telecommunications regulator Arcep (2006): the average cost estimated by Arcep (€500) has been decreased to take into account that in Paris the roll-out of the fibre is less expensive due to the possibility of exploiting the sewage system. A sanity check of this value has been carried out by comparing with the value inferred directly using Citéfibre available data. The up-front cost is therefore assumed to be equal to €400.

Figure 9 – Revenues lost by investing one year later



The annualized volatility of the log return has been estimated using bi-weekly stock returns. Since Citéfibre was floated on Euronext on the 2nd December 2005, the sample size is slightly above 45 observations. A higher frequency would have increased the accuracy of the estimate by increasing the number of observations; however this might have entailed an

²⁴ Prior to December 2005 Citéfibre was not traded and thus this is the first market capitalisation available.

upward biased due to the very low liquidity of the stock. The Citéfibre input data are shown in Table 1.

Table 1 – Citéfibre input data

NPV <i>(Asset price)</i>	€ 7,027
UI <i>(Upfront costs-Strike price)</i>	€ 400
PO <i>(Pay Out)</i>	1.2%
R_f <i>(Risk free rate)</i>	5.5%
VOL <i>(Volatility)</i>	0.78
YtE <i>(Years to Expiry)</i>	6

4.1.1.2 – Established telecommunication operator inputs

Parameters of an NGN investment by an established telecommunication operator differ significantly from those applicable to a start-up firm. This is because all parameters and outcomes have to be evaluated in incremental terms. For instance, the expected NPV of the project is not equal to the overall project cash flow but it is computed as the incremental revenues following the introduction of the new asset. The same logic applies to the evaluation of the payout ratio and of up-front costs.

Also, in the case of the established operator, per unit up-front cost is based on the Arcep study. The input value to the model takes into account that an established operator has to incur some capital expenditures anyway (for instance, for the maintenance and upgrade of traditional copper lines), even if it does not undertake the NGN investment.

The annual payouts (incremental revenues + cost savings) are computed as in the Citéfibre example. The annual payout is thus equal to the difference between the NPV of the cash flows if the investment is undertaken today and the net cash flows realised in the

case of a 1-year postponement. The NPV is obtained by applying the perpetuity formula to the annual net cash flow generated by the introduction of the new asset.

The net cash flows associated with an NGN project for an established operator do not arise only from incremental revenues but also by cost savings. This clearly affects the volatility of the NPV, since cost savings are reasonably steady and predictable. We have assumed that in the case of an established operator half of the net cash flows derive from incremental revenues: the VOL variable for an established operator is thus set equal to half of that of Citéfibre²⁵. Table 2 shows established telecommunication operator input data.

Table 2 – Established telecommunication operator inputs data

NPV <i>(Asset price)</i>	€ 1,485
UI <i>(Up-front costs-Strike price)</i>	€ 440
PO <i>(Pay Out)</i>	4%
R_f <i>(Risk free rate)</i>	5.5%
VOL <i>(Volatility)</i>	0.45
YtE <i>(Years to Expiry)</i>	6

²⁵ This might lead to some underestimation of the actual volatility since also the cost saving part is subject to a certain degree of volatility, depending on the mix of single-play and multiple-play offers. Cost savings induced by an NGN deployment are significantly more relevant when customers subscribe to multiple-play offers (e.g. voice and internet access, or voice and IPTV etc). A sensitivity analysis has thus been conducted by assigning to the cost saving half of the average volatility of main historical European operators.

4.2 – Model outcome and the role of regulation

As already said, we follow the Cox *et al.* (1979) model to investigate the impact of different regulatory regimes onto NGN investment decisions. Its outcomes include expected optimal investment timing and optimal investment policy (i.e. critical values)²⁶. Since the timing of the investment is of particular interest to policy makers and to national sectors regulators, we will focus on the interval between when the investment opportunity arises and when the investment is expected to be undertaken, named *fugit*. The central results of the simulations for the input data shown in Tables 1 and 2 are represented in Figure 10.

Figure 10 – Number of years before the investment is undertaken

Cit�fibre	Established Operator	
Forbearance	Forbearance	Permanent regulation
0	0	2.04
	Sunset Clause	Regulatory holiday
	1.95	0

For the sake of simplicity we divide the project lifespan into three phases. The first phase includes the first six years of the project lifespan, which we define as the “volatile” phase. The second phase (the “steady” phase) embraces years from the seven to the twelve, while the third phase (the “terminal” one) includes the remaining years of the project lifespan (from the thirteen to infinity). Differently from the steady and the terminal phases, to refrain from the irreversible decision entails an insurance value in the volatile one.

²⁶ Critical values can be used to determine the optimal subsidy i.e. the artificial increase of the NPV (either in absolute term or expressed as a percentage) enabling a change of the today optimal policy outcome from “delay the investment” to “invest now”.

The parameters used for Citéfibre reflect the assumption that the new entrant operates in absence of any regulation. By calibrating the model with the parameters of the new entrant operator (see Table 3), we obtain a *fugit* variable equal to 0 (highlighted cell). The model correctly predicts that the optimal policy for Citéfibre in the second half of 2005 was to undertake the investment (which it did).

The volatility of returns on the investment carried out by the Parisian FttH operator is such that any reduction of cash flows during the “volatile phase” (top row; left column) or of cash flows in the “steady phase” (middle row; left column) tilts the decision to invest. Thus, all regulatory interventions on the new entrant would prevent it from investing. The outcome and a sensitivity analysis for a new entrant operator are presented in Table 3.

The sensitivity analysis concerns the up-front cost of the investment (strike price), which is allowed to vary by $\pm 12\%$ with respect to the base value; the payout rate, whose interval is assumed to lie in between ± 0.5 around the central value of 1.2%; the volatility, which we allow to be lower than the reported value of 0.78, if the stock were more liquid; the NPV (asset price) of the project which can vary by $\pm 20\%$. In most cases, the optimal time to invest remains “now”. As expected, the investment tends to be deferred (up to almost four years) when the investment cost rises or its payout falls; on the other hand, as the NPV decreases, the project is delayed because the probability of not recovering the upfront costs increases.

Table 3 – Citéfibre outcomes data

		Volatility								
		0.623			0.700			0.777		
Up-front cost	Payout rate	NPV								
		5622	7027	8432	5622	7027	8432	5622	7027	8432
352	0.007	2.04	0.00	0.00	2.27	1.88	0.00	3.36	2.33	1.96
	0.012	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.00	0.00
	0.017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	0.007	2.16	1.76	0.00	3.24	2.15	1.51	3.68	2.39	2.25
	0.012	0.00	0.00	0.00	1.52	0.00	0.00	2.27	0.00	0.00
	0.017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
448	0.007	3.09	2.05	0.00	3.55	2.27	2.05	3.78	3.37	2.36
	0.012	0.00	0.00	0.00	2.15	0.00	0.00	2.38	2.16	0.00
	0.017	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00

We can now turn to the case of the established operator. While in the case of the new entrant we assumed absence of any regulation, with the established operator we are interested at looking at the impact of different regulations on the timing of investment. We consider four different regulatory scenarios: 1) *Forbearance* (absence of regulation); 2) *Permanent regulation*; 3) *Sunset clause*; 4) *Regulatory holiday*. The intervention by the regulator consists of a decrease in the annual net cash flow of the established operator by 27.5%. This reduction corresponds to a halving of the cost savings and the extra profits of NGNs.

Initially we assume that the established operator is the only one which is evaluating whether to invest in NGNs: the competitive situation is such that no alternative operator is looking at building a next generation infrastructure. Therefore the incumbent has not to rush (or delay) the investment in order to compete with infrastructure-based new entrants (or to exploit somebody else's network). In practice, with limited exceptions such as Fastweb in Italy and Free in France, so far only incumbents have announced wide-ranging investment plans in NGNs: the assumption can thus be considered quite realistic. On the

other hand, by neglecting the competitive interplay between established operators and competitors, a relevant factor in deciding the optimal timing of investment in NGNs might be missed.

Regulatory forbearance. The regulatory forbearance consists of withdrawing sector-specific *ex ante* regulation on next generation networks, i.e. mandated access to the infrastructures and setting of the price at which access is imposed²⁷. In the regulatory forbearance, the authority leaves returns uncapped in both the volatile and the steady phase. The forbearance scenario is modelled by assigning to the NPV and PO their initial values i.e. those included in Table 2.

Results (see Figure 10 for a summary and Table 4 for the whole set) are obtained by setting the up-front investment equal to €440 and the volatility equal to 0.45: they are shown in the highlighted 3x3 matrix of Table 4. In the forbearance scenario (bottom row; right column), which corresponds to the highest payout rate and NPV, investment is undertaken immediately.

Sensitivity analysis is conducted on the investment up-front cost ($\pm 14\%$) and on volatility. In all cases, except when the up-front investment cost and volatility take both their highest values, in which case *fugit* is equal to two years, forbearance leads to immediate investment.

From the point of view of our model, the regulatory forbearance is the most effective solution in order to enhance investments. In fact the company decision to invest is based on expectations of unconstrained net cash flows (both NPV and payout are unconstrained).

Clearly, our framework is inadequate to examine the competition issues raised by the regulatory forbearance, which are causing so much concern with the European Commission and regulators everywhere in Europe. In fact our model is only concerned with the amount and the timing of investments: hence a regulatory forbearance is a first best solution almost by construction.

²⁷Regulatory forbearance on the roll-out of optical fibre has taken place in US following a petition by Verizon to the Federal Commission for Communications.

In order to take care of the concerns by the EC, we should have introduced a different objective function, based on the consumers' welfare (or possibly the total welfare), to be maximised. There are basically two ways to do so. One is to introduce the amount of investment directly in the welfare function, as in Brandão and Sarmento (2007) and Kalmus and Wiethaus (2006): the argument is that investment increases the quality of service, hence benefits consumers directly. In the case of next generation networks, it can be argued that new fibre infrastructures will indeed reduce the number of technical faults in the network. However, in this case, the model would not include an obvious trade-off between the degree of competition and the amount of investment. The second possibility is to incorporate in the model the notion that, if forbearance leads to less competition in the marketplace and therefore to an exit of alternative operators, then the established operator which builds the NGNs may have to forego some extra revenues at the wholesale level. These extensions are left for future work.

Permanent regulation. This measure is at the opposite extreme of the regulatory spectrum than forbearance. The idea is that incumbent operators are forced by the regulator to supply a wholesale service (bit-stream) based on NGN on request to alternative operators. This option has been entertained by several European regulators, including the Italian one. European established operators have usually retorted that the sale of wholesale services based on NGN should take place under commercial freedom. Of course, one crucial issue is the price of the wholesale service: Ofcom for instance has mentioned the possibility to adjust the reference price of the NGN bit-stream in order to take into account the risk of the investment.

In a permanent regulation scenario, national regulatory authorities cap returns both in the volatile and in the steady phase. Permanent regulation is modelled by a 27.5% reduction of PO, whose rate now becomes equal to 4%, and by a reduction of the NPV equivalent to a 27.5% of the cash flow over a period extended to 12 years, which is now equal to €1,291.

The lost payout, the expected NPV at the initial date and the NPV at expiry are all reduced as a consequence: it becomes more convenient not to exercise the option than in the forbearance case. As it can be seen in Table 4, the permanent regulation scenario

(middle row, left column) implies in fact an expected postponement of the investment of about two years²⁸. Sensitivity analysis suggests that the delay increases with the strike price and the volatility, up to 3.48 years when both parameters take their maximum values in the exercise.

Sunset clause. Sunset clauses are a regulatory tool which is more widespread in the US than in Europe. Still, it could help to overcome some of the regulatory concerns raised by the deployment of NGNs. The measure is that established operators which build new networks are compelled to provide a wholesale permanent regulation bit-stream service based on NGN, such as the one we discussed in the previous case, for a pre-determined period of time. The rationale is that established operators can allegedly exploit the advantage of having a larger market share to start with: hence, in principle, they need less time to recoup the massive investment costs of NGNs. With a sunset close obligation, alternative operators can make use of the established operator's infrastructures, while they build their own customer base and overcome the initial competitive disadvantage. After a pre-defined number of years, the established operator is no longer obliged to rent the NGN infrastructures at a cost and the alternative operators may either rent at commercial conditions or build their own networks. The main rationale of the sunset clause is that it creates the proper incentives for alternative operators to build their own infrastructures, while at the same time reducing only partially the incentive for the established operator to construct its own network.

The sunset clause scenario corresponds to a regulatory policy which intervenes in the volatile phase, while it leaves returns uncapped in the steady phase of the project. In terms of our model, the sunset clause scenario is modelled by subtracting to the initial value of the NPV the 27.5 % of the net cash flow realised over a six year period (NPV is thus equal to €1,388) and by reducing the initial PO by 27.5%, down to 4%. The sunset clause (middle row centre column) results in a expected investment postponement of almost two years (1.95).

²⁸ Again, our model is not suited to examine the consequence of such measures on the degree of competition in the telecom markets.

Albeit the sunset clause can be preferred on theoretical grounds, our simulation suggests that investment in NGNs ends up being postponed by almost the same amount of time as in the permanent regulation case. This is because it affects the investment return during the period – the first six years - in which it matters most for the purpose of the investment decision, as uncertainty is still high and it makes sense to wait before undertaking the project.

The sensitivity analysis shows that the waiting time is typically either zero or around two years. Only when volatility and the up-front cost take the highest values, then the postponement overcomes three years. In all instances the waiting time in the sunset clause is slightly lower than the corresponding time under permanent regulation.

Regulatory holiday. This is another intermediate solution between the regulatory forbearance and the permanent regulation. The regulator should impose no regulatory obligations on the investments implemented in the initial period of the project up to the expiry date. The rationale is that, in a real option framework, it is the uncertainty on the distribution of future cash flows, hence of the net present values, which causes the company to put off the project. As we saw, such uncertainty is very high at the beginning, when the value of the reversibility (or protection) component is at its zenith. Uncertainty, hence the insurance element, tends to become smaller in the following periods. If the aim of the regulator is to create an environment conducive to investments, then it may decide to scrap all regulatory obligations until uncertainty becomes sufficiently small. After that date, the regulator can impose obligations with an impact on cash flows.

The benefit of a multiphase regulation policy that adjusts its tightness to the expected decrease of the risk over time is twofold: it would act as an effective incentive where it is needed (i.e. when the protection value against downside potential would refrain telecommunication operators from investing); when the circumstances will be such as to justify fibre deployment irrespectively of the regulatory context, the major benefit of the investment could be directly transferred to consumers through the promotion of a fiercer service based competition at retail level.

The proposed regulatory policy differs substantially from the regulatory holiday called for by Deutsche Telekom²⁹ for two main reasons: 1) it does not require a removal of all forms of regulation (access, non discrimination, transparency obligation may indeed be preserved) but it simply envisages a more favourable rate of return on investments undertaken in the volatile phase; 2) the timeframe of the lenient regulatory phase is to be set according to the reduction in the volatility rather than being based on the operator actual investment plan: if the established operator does not launch its service within a certain date, the more favourable regulatory conditions will be foregone³⁰.

The regulatory holiday scenario is modelled by subtracting to the NPV initial value 27.5% of the net cash flow realised over a six year period (down to €1,388)³¹, whereas the value of the payout rate is left as in the forbearance case (5.5%). The regulatory holiday scenario (bottom row; middle column) results in immediate investment, as in the forbearance case. This can be explained by the fact that the regulatory intervention applies only to the period when uncertainty on the project returns is gone: hence, it does not affect the decision on whether to undertake the project.

If we vary the values of the parameters, the *fugit* time remains basically unaffected and equal to zero. Only when the up-front cost increases, then the investment is delayed by around two years also in the regulatory holiday scenario.

In all scenarios the terminal phase of the project is assumed to be fully competitive and thus out of the scope of regulation³².

²⁹ In Germany, it was introduced through a specific amendment to the German Law of Telecommunications. Such legal provision has been fiercely opposed by the European Commission on the ground that the established operators would be able to limit the availability of access of new entrants, undermining competition in the market place. On this issue the EC has started an infringement procedure against Germany.

³⁰ The regulatory holiday invoked by Deutsche Telekom would be effective from the date of deployment.

³¹ The impact of regulation on NPV is measured as a percentage reduction of the cash flows accrued in the period regulation operates. Due to discounting the absolute value of foregone cash flows in a sunset clause scenario would be higher than absolute value of foregone cash flows due to a sunset clause policy. However since the aim of the model is to compare how the two alternative regulatory regimes perform in terms of incentives to invest with respect to their different time scopes we decided to neglect the discounting effect. This is done by applying the same NPV reduction both under the regulatory holiday scenario and the sunset clause scenario.

³² Note that in the sunset clause and in the regulatory holiday regimes, the length of the volatile and that of the steady phase have been purportedly chosen to be the same in order to avoid that the model outcomes were influenced by the different time length of the period subject to regulation.

By increasing the volatility (VOL) up to 0.5, the optimal policy associated with sunset clause or permanent regulation increases the expected investment postponement to more than two years, while in the other two scenarios it does not change. Conversely, by setting the VOL equal to 0.4 the optimal policy suggests not to invest in the permanent regulation scenario, while it dictates an immediate investment commitment under all other scenarios.

Table 4 – Established telecommunication operator outcomes data

		Volatility								
		0.401			0.450			0.500		
Up-front cost	Payout rate	NPV								
		1291	1388	1485	1291	1388	1485	1291	1388	1485
378	0.025	1.93	1.84	1.69	3.06	2.58	1.96	3.36	3.29	2.98
	0.040	0.00	0.00	0.00	1.37	0.00	0.00	2.07	1.91	0.00
	0.055	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	0.025	3.18	2.96	1.93	3.39	3.26	3.16	3.93	3.48	3.41
	0.040	1.78	0.00	0.00	2.04	1.95	1.38	2.78	2.15	2.07
	0.055	0.00	0.00	0.00	0.00	0.00	0.00	2.08	0.00	0.00
502	0.025	3.90	3.29	3.16	4.09	3.87	3.39	4.31	4.19	3.93
	0.040	2.01	1.94	1.64	3.17	2.10	2.04	3.48	3.25	2.17
	0.055	0.00	0.00	0.00	2.08	1.77	0.00	2.25	2.18	2.08

As general result we note that, as expected, a sunset clause approach always induces a longer expected investment postponement than that induced by a regulatory holiday. This is equivalent to say that, all other conditions being equal, in terms of investments incentive, the regulatory holiday scenario performs always better than sunset clause scenario.

Duopoly. In this scenario we relax the assumption that it is only the incumbent operator which invests in NGNs. We assume that a second, smaller, operator exists in the market and that it too intends to invest in next generation networks. For the sake of simplicity we assume that the alternative operator aims at a market share in NGN access and services of 35%, which corresponds roughly to the average market share in the broadband market of

alternative operators according to the Ecta scorecard. Hence the future revenues stream of the established operator (the NPV) will be reduced by 35% with respect to the baseline case of a single monopolist³³.

The opening up of the market to competition will affect the timing of the investment decision vis-à-vis the case of a single monopolist. Two opposite forces are at work here. One is the already mentioned reduction in future revenues due to the existence of a competitor: this is tantamount to a (negative) income effect, which decreases the NPV and puts off the beginning of the investment.

The second force depends on who is the first to invest, whether the incumbent or the alternative operator. If the established operator is the first mover, *prima facie* we can assume that the operator incurs in no specific cost in order to attract its customer base, vis-à-vis the monopolist case³⁴. In other words, the demand for NGN services requires no particular advertising campaign for the first mover.

Let us suppose now that the established operator has to catch up with a competitor which has already started to invest in next generation networks. Thus, in order to reach its long-term market share which we assume to be equal to 65%, the incumbent needs to make an additional effort to subtract part of the *clientèle* from the alternative operator, by facing extra costs. We assume that these costs are identical to the ones that an operator faces in order to conquer customers from competitors in the broadband market, i.e. xx euro per client. These costs would reduce the payout by an equal amount: hence it is in the interest of the operator to speed up the beginning of the investment with respect to the monopoly case. Hence this effect goes in opposite direction than the reduction in NPV.

Such a cost asymmetry between being a first or a second mover is a bit artificial of course. It is more likely that both operators face subscriber acquisition costs (maybe not of the same amount) independently of whether they act as first or second. We would need a full blown theoretical model in order to study how the two operators can leapfrog each other in this case, while here we take the pecking order for granted. However it is still

³³ The implicit assumption is that the price of NGN access and services is the same for the established and the alternative operators

³⁴ Excluding the reduction in NPV generated by the presence of a competitor

interesting to give a feeling on how simulation can change when a modicum of competition is included.

5 – Concluding remarks

In this paper we constructed a real option model in order to study the investment decision of telecommunications operators in next generation networks (NGNs). In particular we try to answer the question on whether the extension of current regulatory obligations on dominant companies may hamper the investment in NGNs or not. The real option model allows to capture the vast uncertainty surrounding the projected returns and cost savings of services based on NGNs both for established operators and new entrants and thus to attach an economic value to the option of postponing the investment decision.

We concentrate on the timing of the investment as the relevant variable, thus neglecting both the amount of the investment and the impact on consumers' welfare. The latter omission is of particular concern as, when it comes to assess the different regulatory regimes, our analysis is *per force* limited at best. We hope to include the welfare aspect in future extensions of this work. Another possible extension concerns the introduction of more than one players in the market and how does this affect the timing of the investment.

An interesting feature of the real option model regards the so-called truncation issue: regulatory intervention that caps the total returns affects investments in NGN negatively *only in the initial period*; in the long run, according to the real option model, investments are not affected insofar as the portion of the net present value distribution which lies below the strike price remains unchanged even after the truncation imposed by the regulator.

We calibrate the real option model with actual data coming from a floated new entrant operator, Citéfibre, specialised in services based on optical fibre; we make also use of estimates for incumbent operators (there are not actual data available, yet), based on a number of studies and reasonable conjectures. The output of the model suggests that the new entrant was right in undertaking the investment when it did: this is of some comfort as to the model robustness.

In the case of the established operator, we consider four alternative regulatory regimes: 1) *Forbearance* (absence of regulation); 2) *Permanent regulation*; 3) *Sunset clause* (regulation only in the initial period of the project, so as to incentive investment in alternative infrastructures); 4) *Regulatory holiday* (absence of regulation in the initial period of the project, when uncertainty on the returns is particularly high). The intervention by the regulator is modelled as a decrease in the annual net cash flow of the established operator by 27.5%. This reduction corresponds to a halving of the cost savings and the extra profits of NGNs.

The outcomes of the simulations suggest that investment is carried out immediately under forbearance (as expected) and regulatory holiday regimes; it is delayed by around two years in the other cases. As far as the timing of the investment is concerned, the regulatory holiday appears superior to the other regulatory options.

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